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Experimental Study on Mold-Lay Filament instead of Wax in Investment Casting Process

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Abstract

Metal casting with investment casting method is metal casting which has the ability to produce accurate parts and has a controlled fineness. Current technological developments are very influential in the development of investment casting. One of them has been found mold-lay filament as a substitute for wax, which is now wax is one of the main components in investment casting process. Mold-lay filament is printed using a 3D Printer machine. In this study, the wax in the investment casting process was replaced by a mold-lay filament with the specifications 0.75kg / 0.55 lb of 1.75mm MOLDLAY filament, prints at temperatures of 170-180 ° C. The result show that mold-lay flutes are also able to come out well from slurry molds, but require more time than wax, this is because one of the plastic mold-lay compositions, which takes a long time for the moldlay fillment to come out of the mold. Further research suggestions are needed further testing in terms of roughness of the product with moldlay filament and compared with wax. This will also see if there are any remaining moldlay filaments from the mold.

Keywords*: moldlay; investment casting; wax*

1. INTRODUCTION

Metal casting is one of the most important technologies for manufacturing complex parts. Investment casting or knonw as lost wax casting is casting method which has ability to produce complex parts with excellent surface finish and high accuracy on complex shapes [1][2]. This phenomena makes investment casting to be difficult to be analyzed and modelled [3]. *Investment casting* or known as precision casting are widely used in automotive industry, aerospace industry, machine building, chemicals and even medicine industry [4]. With the advantages possessed by investment casting, many researchers carried out a variety of studies such as numerical simulations of the wax injection process [5][6], wax material compositon with other other elements, especially in the vacuum casting process on the surface quality of the cast metal [7], camphor and needle coke to enhance the porosity of ceramic shell [8], the effect of variations of wax burning time on product accuracy [9] and numerical simulation of transient heat transfer using phase change material (pcm) with COMSOL multi-physics software [10].

In investment casting, it is need to be careful in formulating wax to ensure dimensional stability and no contraction during heat variations and cooling steps in mold preparation [11][12]. In its development, the use of 3D printing [13] for making molds in investment casting has begun to be utilized, such as the use of machines based on the process of stereolithography (SLA) [14]. The 3D printing machines are devices that are simple, flexible and have a cost effective approach to produce a physical model of a component [15]. Filaments that are commonly used in 3D printing made from polymers include polylactic

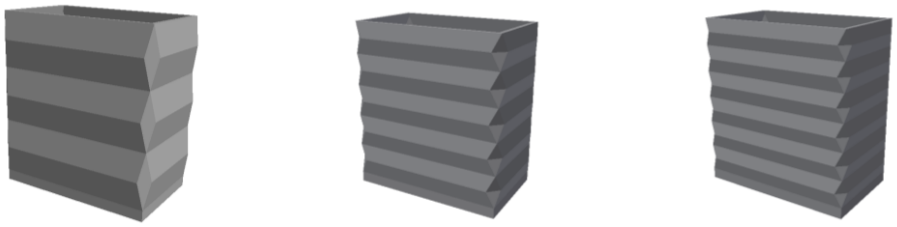
acid (PLA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate (PET), thermoplastic polyurethane (TPU), high impact polystyrene (HIPS), polyvinyl alcohol (PVA), and nylon [16][17][18]. The ability of PLA to produce components with high accuracy has been investigated in the fabrication of micro needle arrays [19]. Currently developing filament that serves as a substitute for wax on investment casting, namely mold-lay filament. Mold-lay is an ideal material for permanent casting and investment casting. With a printing temperature of 170-180 ° C, similar to the conditions used to print with PLA. The main difference between mold-lay and other plastics is the transition of the material into a liquid with very low viscosity when heated to 270 °C. This allows it to flow easily from the mold cavity [20]. In this research mold-lay will be used to replace wax in investment casting and to test the ability of mold-lay fillament in the slurry coating process and mold-lay filament ability in the dewaxing process.

2. METHODS

The study focus on mold-lay filament as subtituted of wax in investment casting. Mold-Lay fillament is a filament that functions like wax, which is structurally unchanged, is also able to maintain its shape at room temperature and will melt as wax when heated to 270^{o}C. This research method is taken in several steps, namely design, printing with a 3D Printer, making a gate system, making slurry

2.1 Design

In this study, the design of origami crash box use 3 types of design, namely 3 segments, 5 segments and 6 segments. The design of the object has a machine length of 114.5 mm, a width of 68.5 mm and a height of 126 mm with a thickness of 3 mm [21][22]. This design has several difficulties in the process of making gates and the slurry coating process, due to the complex and sharp angular shape in each segment. The design of the origami pattern crash box can be seen in Figure 1.



a) 3 segmen b) 5 segmen c) 6 segmen

Figure 1. Crash *box origami pattern*

2.2 3D Printing Process

The next step after completing the 3D design process is to convert the cad file into *.stl* form, and opened by flash print software. Printing settings on the 3D printer machine with a layer height of 0.1 mm, 100% fill density, print speed of 40 mm / s, extruder temperature of 120^{o}C and bed temperature of less than 30^{o}C. The filament specifications are with a diameter of 1.75mm. 3D printer settings and processing process can be seen in Figure 2, the average time needed in the process of processing around 29 hours per design and requires 61.9 meters of material per design, details of this data can be seen in Table 1.

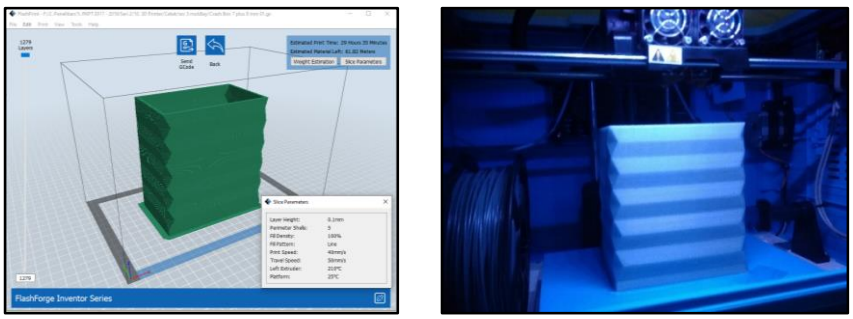


Figure 2. Software flash print and printing process

Table 1. Time and needed material

Type	Origami pattern	Time	Material
First	3 segments	30 h 18 m	63,03 meters
Second	5 segments	29 h 35 m	61,82 meters
Third	7 segments	29 h 9 m	60,90 meters

The results of the 3D printer products are ilustrated in Figure 3. Each design is printed twice, and has taken 174 hours and 371.5 meters. The evaluation of printing 3d printer with mold-lay filament is a print bed below 30^{o}C, if given a temperature of 30^{o}C, the filament attached to the bed will be curved, this can be seen in the print of a 3-segment origami pattern crash box. This is because the filament that attaches to the bed is continuously exposed to heat, and makes the filament warped, to overcome this problem, giving a bed temperature of 20-25 ^{o}C in a printing process that takes a long time.

Figure 3. The result of 3D printer

2.3 Making Gate System

The design of the gate of metal into the mold is a challenge because origami-shape that have many angles, and a thickness of 3 mm. What is done in this process is designing channels, making runners and making channels. Runner function is to determine the model of the entry of metal liquid when pouring, to go to the angle of the object. The shape of the runner can be seen in Figure 4a. Figure 4 is the process of assembling runners with objects. The assembly process is carried out with the help of a soldering equipment, so that the model with the runner can be fused.

a) runner model b) assembly c) runner system

Figure 4. Assembly process with runner

2.4 Making slurry

The composition of making slurry is zircon flour and colloidal silica, with the addition of wetting agent and deep foarmer. The common ratio used in making slurry is zircon flour as much as 4 kg, colloidal silica 1 L with added wetting agent and deep foamer each of 5 drops. Function of the wetting agent as a slurry binder and deep foarmer as a slurry hardener. Making slurry requires checking the liquidity of the slurry liquid, when the slurry is too runny, the slurry cannot stick to the model. The liquidity checking process with a baumeter equipment, but in this checking process, the researchers used a tube-shaped object with a volume of 50 ml and was given a hole at the bottom. Slurry can be said to meet the standard when slurry runs out within 15s.

3. RESULT AND DISCUSSION

3.1 The Ability of Fillament on Slurry Coating Process

Slurry coating testing has several stages, namely slurry coating, zircon sand coating, mullite coating. The first coating test is a slurry coating with the target coating on the outside and inside, able to stick to the model. The next layer after the slurry is perfectly attached, the coating is followed by the zircon sand coating. The zircon sand coating functions as a refiner of the model pattern, the zircon sand coating process can be done twice. Furthermore, slurry coating and fine mullite twice, medium mullite 3 times and coarse mullite 3 times. Slurry coating is carried out at each step of the coating, for example slurry coating, fine mullite coating, slurry coating, fine mullite coating, slurry coating, moderate mullite coating, and so on.

In each coating process is left to stand for 3 hours, this serves so that the material covering the model is perfectly attached. After the coating process is complete, the next step is the process of planting the model for 24 hours. The process of coating the slurry is not only on the outside, but the inside is also perfectly coated with the slurry. The process of beginning to the end coating can be seen in Figure 5. In this study, it can be concluded that the mold-lay filament can be coated with slurry according to the wax function in the investment casting process. After the mold-lay filament is coated with slurry, it is referred to as a mold.

Figure 5. Slurry coating

3.2 The Ability of Fillament on Slurry Coating Process

The next test is testing the ability of the moldl-ay filament in the dewaxing process. Dewaxing is the process of removing wax from a mold by heating it to a certain temperature. This test is needed, to know the ability of the mold-lay filament to melt properly. When the filament is not able to melt completely, it will cause defects in casting during the pouring process. This testing process by heating the mold with a bunner, the burner is designed like a blower with a long handle, this is to facilitate the reach of each side of the mold, as shown in Figure 6.

Figure 6. Dewaxing process

The results of this study can be said that the mold-lay filament is able to come out of the mold, but with a longer time than wax around 10 minutes, this is because one of the compositions of the moldlay filament is plastic and requires a higher temperature than the wax to melt the mold-lay filament, due to the liquid temperature of the mold-lay filament

270 ºC, while the wax material has a flash point temperature of 200-240 ° C. The results of the dewaxing process can be seen in Figure 7, it appears that the mold is able to form a perfect pattern of objects, and the mold-lay filament is able to come out of the mold. In further research is needed study on the pouring process, this is to see if there is any residual from the mold-lay filament from the mold.

Figure 7. The result of dewaxing process

4. CONCLUSIONS

1. Mold-lay Fillament able to be coated by slurry, zircon sand and mullite completely, it can be seen from the coating that is able to stick well.
2. The mold-lay fillament is able to come out well from the slurry mold, but requires more time than wax, this is because the mold-lay composition is plastic, which takes a long time for the mold-lay fillment to come out of the mold.
3. Further research requires the testing in terms of roughness of the product with mold-lay filament and compared with wax. This will also see if there are any remaining mold-lay filaments from the mold.

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